A&A 379, 976–991 (2001)
DOI: 10.1051/0004-6361:20011385

Astronomy & Astrophysics

Chromospheric activity, lithium and radial velocities of single late-type stars possible members of young moving groups*,**

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Received 23 July 2001 / Accepted 26 September 2001

Abstract. We present here high resolution echelle spectra taken during three observing runs of 14 single late-type stars identified in our previous studies (Montes et al. 2001b, hereafter Paper I) as possible members of different young stellar kinematic groups (Local Association (20–150 Myr), Ursa Major group (300 Myr), Hyades supercluster (600 Myr), and IC 2391 supercluster (35 Myr)). Radial velocities have been determined by cross correlation with radial velocity standard stars and used together with precise measurements of proper motions and parallaxes taken from Hipparcos and Tycho-2 Catalogues, to calculate Galactic space motions (U, V, W) and to apply Eggen's kinematic criteria. The chromospheric activity level of these stars have been analysed using the information provided for several optical spectroscopic features (from the Ca II H & K to Ca II IRT lines) that are formed at different heights in the chromosphere. The Li I λ6707.8 Å line equivalent width (EW) has been determined and compared in the EW(Li I) versus spectral type diagram with the EW(Li I) of stars members of well-known young open clusters of different ages, in order to obtain an age estimation. All these data allow us to analyse in more detail the membership of these stars in the different young stellar kinematic groups. Using both, kinematic and spectroscopic criteria we have confirmed PW And, V368 Cep, V383 Lac, EP Eri, DX Leo, HD 77407, and EK Dra as members of the Local Association and V834 Tau, π^1 UMa, and GJ 503.2 as members of the Ursa Major group. A clear rotation-activity dependence has been found in these stars.

Key words. stars: activity – stars: chromospheres – stars: late-type – stars: abundances – stars: kinematics – galaxy: open clusters and associations: general

1. Introduction

It has long been known that in the solar vicinity there are several kinematic groups of stars that share the space motions of well-known open clusters. Eggen (1994) defined a "supercluster" (SC) as a group of stars, gravitationally unbound, that share the same kinematics and may occupy extended regions in the Galaxy, and a "moving group" (MG) as the part of the supercluster that enters the solar neighbourhood and can be observed all over the sky. The origin of these stellar kinematic groups (SKG) could be the evaporation of an open cluster, the remnants of a star formation region or a juxtaposition of several little star formation bursts at different epochs in adjacent cells of the velocity field. The youngest and best-documented SKG are: the Hyades supercluster (600 Myr) the Ursa Major group (Sirius supercluster) (300 Myr), the Local Association or Pleiades moving group (20 to 150 Myr), the IC 2391 supercluster (35–55 Myr), and the Castor moving group (200 Myr) (see Montes et al. 2001b, hereafter Paper I, and references therein).

Well-known members of these SKG are mainly early-type stars and few studies have been centered on late-type stars. However, the identification of a significant number of late-type population in these young SKG is extremely important for the study of the chromospheric activity and could lead to a better understanding of star formation history in the solar neighbourhood. In our previous work (Montes et al. 2000a, 2001a; Paper I) a sample of late-type

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* Based on observations made with the 2.2 m telescope of the German-Spanish Astronomical Centre, Calar Alto (Almería, Spain), operated by the Max-Planck-Institute for Astronomy, Heidelberg, jointly with the Spanish National Commission for Astronomy, with the Nordic Optical Telescope (NOT), operated on the island of La Palma jointly by Denmark, Finland, Iceland, Norway and Sweden, in the Spanish Observatorio del Roque de Los Muchachos of the Instituto de Astrofísica de Canarias, and with the Isaac Newton Telescope (INT) operated on the island of La Palma by the Isaac Newton Group in the Spanish Observatorio del Roque de Los Muchachos of the Instituto de Astrofísica de Canarias.

** Tables 1, 4, and 5 are only available in electronic form at the CDS via anonymous ftp to
cdsarc.u-strasbg.fr (130.79.128.5) or via
http://cdsweb.u-strasbg.fr/cgi-bin/qcat?J/A+A/379/976

Article published by EDP Sciences and available at http://www.aanda.org or http://dx.doi.org/10.1051/0004-6361:20011385

stars of previously established members and possible new candidates to these five young SKG have been identified. In order to better establish the membership of these candidate stars in the different young SKG, we have started a program of high resolution echelle spectroscopic observations. The spectroscopic analysis of these stars allows us to obtain a better determination of their radial velocity, lithium (λ6707.8 line) equivalent width, rotational velocity and the level of chromospheric activity. We will use all these new data to study in detail the kinematics (Galactic space motions (U, V, W)) of these stars, apply age-dating methods for late-type stars, and in this way analyse in more detail the membership of these stars in the different SKG.

We present here the results of our first spectroscopy studies of a sample of 14 single late-type stars selected by us in Paper I as young disk stars or possible members of some of the above mentioned young SKG. The high resolution echelle spectra analysed here were taken during three observing runs (from 1999 to 2000) and include all the optical chromospheric activity indicators from the Ca II H & K to Ca II IRT lines as well as the Li I λ6707.8 line.

In Sect. 2 we give the details of our observations and data reduction. The radial velocity and Galactic space-velocity components (U, V, W) determination is described in Sect. 3. The Li I λ6707.8 line is analysed in Sect. 4. The different chromospheric activity indicators are analysed in Sect. 5. Individual results for each star are reported in Sect. 6. Finally, in Sect. 7 the discussion and conclusions are given.

2. Observations and data reduction

The spectroscopic echelle observations of the stars analysed in this paper were obtained during three observing runs:

1) 2.2 m-FOCES 1999/07
This took place on 24–29 July 1999 using the 2.2 m telescope at the German Spanish Astronomical Observatory (CAHA) (Almería, Spain). The Fibre Optics Cassegrain Echelle Spectrograph (FOCES) (Pfeiffer et al. 1998) was used with a 2048^2 15μ LORAL#11i CCD detector. The wavelength range covers from 3910 to 9075 Å in 84 orders. The reciprocal dispersion ranges from 0.03 to 0.07 Å/pixel and the spectral resolution, determined as the full width at half maximum (FWHM) of the arc comparison lines, ranges from 0.09 to 0.26 Å.

2) NOT-SOFIN 1999/11
Observations taken on 26–27 November 1999 using the 2.56 m Nordic Optical Telescope (NOT) located at the Observatorio del Roque de Los Muchachos (La Palma, Spain). The Soviet Finnish High Resolution Echelle Spectrograph (SOFIN) was used with an echelle grating (79 grooves/mm), Astromed-3200 camera and a 1152×770 pixel EEV P88200 CCD detector. The wavelength range covers from 3525 to 10 425 Å in 44 orders. The reciprocal dispersion ranges from 0.06 to 0.17 Å/pixel and the spectral resolution (FWHM) from 0.14 to 0.32 Å.

3) INT-MUSICOS 2000/01
Observations make on 18–22 January 2000 with the 2.5 m Isaac Newton Telescope (INT) at the Observatorio del Roque de Los Muchachos (La Palma, Spain) using the ESA-MUSICOS spectrograph. This is a fibre-fed cross-dispersed echelle spectrograph, built as a replica of the first MUSICOS spectrograph (Baudrand & Böhm 1992) and developed as part of MUlti-SIte COntinuous Spectroscopy (MUSICOS[1]) project. During this observing run, a 1024^2 24μ TEK5 CCD detector was used, obtaining wavelength coverage from 4430 Å to 10225 Å in 73 orders. The reciprocal dispersion ranges from 0.07 to 0.15 Å and the spectral resolution (FWHM) from 0.16 to 0.30 Å.

The sample of late-type stars analysed in this paper as well as the the non-active stars used as reference stars in the spectral subtraction and the radial velocity standards used in the radial velocity determinations are listed in Tables 1 and 2. In Table 1 we give the observing log. For each observation we list date, UT and the signal to noise ratio (S/N) obtained in the Ca II H & K and Hα line regions. Table 2 shows the name, HD number, and other stellar parameters such as the spectral type ($T_{\rm sp}$), color indexes V–R and B–V, rotational velocity ($v \sin i$), rotational period ($P_{\rm phot}$). The V–R and B–V color indexes are obtained from the relation with spectral type given by Landolt-Börnstein (Schmidt-Kaler 1982) when individual values are not given in the literature. Other parameters are taken from the references given in the individual results of each star. The Galactic space motions (U, V, W) given in Table 2 have been determined by us as explained in the next section.

The spectra have been extracted using the standard reduction procedures in the IRAF[2] package (bias subtraction, flat-field division and optimal extraction of the spectra). The wavelength calibration was obtained by taking spectra of a Th-Ar lamp. Finally, the spectra were normalized by a polynomial fit to the observed continuum.

3. Radial velocities and space motions

Heliocentric radial velocities were determined by using the cross-correlation technique. The spectra of the program stars were cross-correlated order by order, using the routine FXCOR in IRAF, against spectra of radial velocity standards of similar spectral types (the stars marked with * in Tables 1 and 2) taken from Beavers et al. (1979). The velocity is derived for each order from the position of the cross-correlation peak. Radial velocity errors for each order are computed by FXCOR based on the fitted peak height and the antisymmetric noise as described by

[1] `http://www.ucm.es/info/Astrof/MUSICOS.html`

[2] IRAF is distributed by the National Optical Observatory, which is operated by the Association of Universities for Research in Astronomy, Inc., under contract with the National Science Foundation.

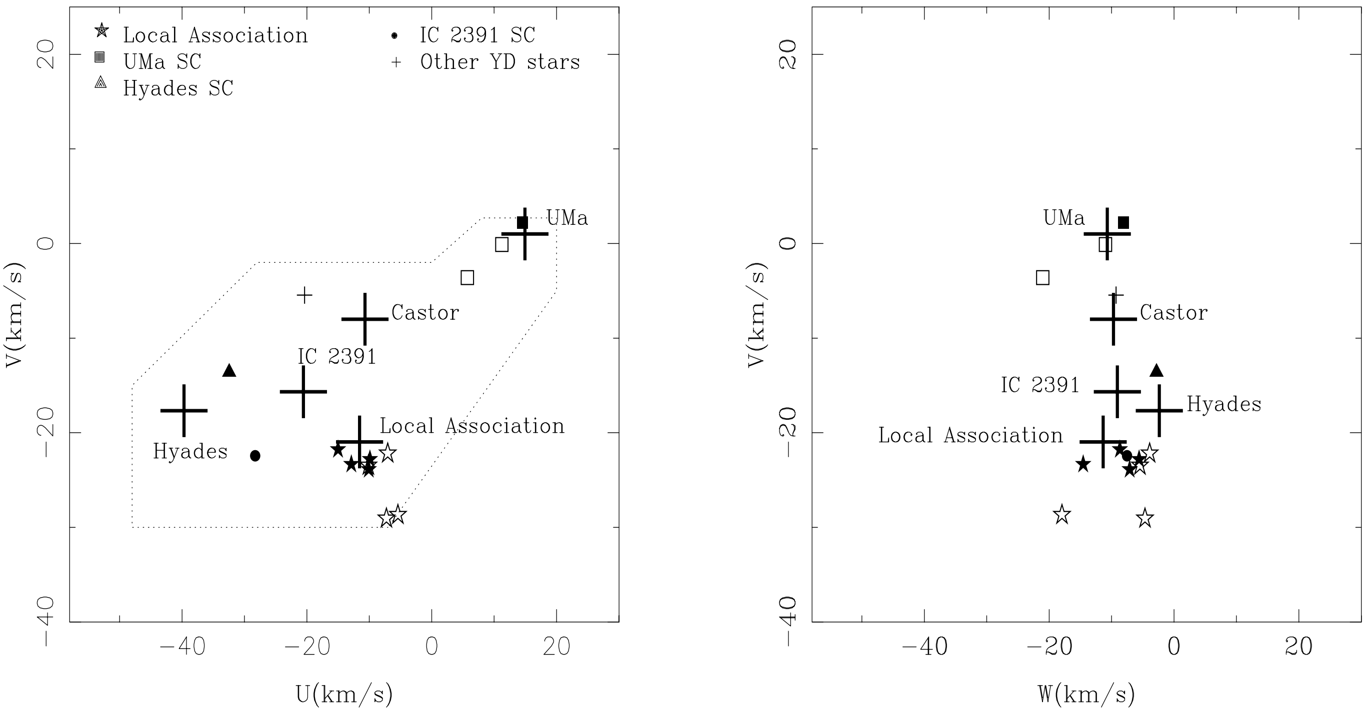

Fig. 1. (U, V) and (W, V) planes (Boettlinger Diagram) for our star sample. We plot with different symbols the stars belonging to the different stellar kinematic groups. Filled symbols are stars that satisfied both of Eggen's criteria (peculiar velocity, PV, and radial velocity, ρ_c), open symbols are other possible members. Big crosses are plotted in the central position of each group. The dashed line represents the boundaries that determine the young disk population as defined by Eggen (1984a, 1989).

Tonry & Davis (1979). In Table 3 we list, for each spectrum, the heliocentric radial velocities ($V_{\rm hel}$) and their associated errors (σ_V) obtained as weighted means of the individual values deduced for each order. The orders including chromospheric features and prominent telluric lines have been excluded when determining the mean velocity. Finally, we also list in Table 3 a mean value for each star, obtained as weighted mean of the individual values deduced for each spectrum.

We have used these radial velocities together with precise measurements of proper motions and parallaxes taken from Hipparcos (ESA 1997) and Tycho-2 (Høg et al. 2000) Catalogues, to calculate the Galactic space-velocity components (U, V, W) in a right-handed coordinated system (positive in the directions of the Galactic center, Galactic rotation, and the North Galactic Pole, respectively). We have modified the procedures in Johnson & Soderblom (1987) to calculate U, V, W, and their associated errors. The original algorithm (which requires epoch 1950 coordinates) is adapted here to epoch J2000 coordinates in the International Celestial Reference System (ICRS). The uncertainties of the velocity components have been obtained using the full covariance matrix in order to take into account the possible correlation between the astrometric parameters. We have used the correlation coefficients provided by Hipparcos (ESA 1997). The obtained values are given in Table 2 and the (U, V) and (W, V) planes (Boettlinger Diagram) are plotted in Fig. 1. In this figure we have also plotted (big crosses) the central position given in the literature (see Paper I) of the five young SKG analysed in this work.

As in Paper I we have used as membership criteria the position of the stars in the velocity space (U, V, W) and the Eggen's kinematic criteria of deviation of the space motion of the star from the convergent point (peculiar velocity, PV) and comparison between the observed and calculated (ρ_c) radial velocities. Using these criteria we have considered PW And, V368 Cep, V383 Lac, EP Eri, DX Leo, GJ 211, HD 77407, and EK Dra as possible members of the Local Association (LA); V834 Tau, π^1 UMa, and GJ 503.2 as possible members of the Ursa Major group (UMa); GJ 577 as a possible member of the Hyades supercluster (HS); GJ 3706 as a possible member of IC 2391 supercluster; and LQ Hya as another young disk (YD) star. More details about the membership of these stars are given in the individual results of each star.

4. The Li I λ6707.8 line

The resonance doublet of Li I at λ6707.8 Å is an important diagnostic of age in late-type stars since it is destroyed easily by thermonuclear reactions in the stellar interior. This line is included in our echelle spectra in all the observing runs. At this spectral resolution and with the rotational velocity ($v \sin i$ > 8 km s^{-1}) of the observed stars the Li I line is blended with the nearby Fe I λ6707.41 Å line. We have corrected the total measured equivalent width, EW(Li I+Fe I), by subtracting the EW of Fe I calculated from the empirical relationship with (B–V) given

Table 2. Stellar parameters.

Name	HD/BD	T_{sp}	$V-R$	$B-V$	$v \sin i$ (km s^{-1})	P_{phot} (days)	$U \pm \sigma_U$ (km s^{-1})	$V \pm \sigma_V$ (km s^{-1})	$W \pm \sigma_W$ (km s^{-1})
LA									
PW And	HD 1405	K2V	0.74	1.00	23.4	1.75	-5.42 ± 0.33	-28.69 ± 0.63	-17.94 ± 0.74
V368 Cep	HD 220140	K1V	0.61	0.87	16.1	2.74	-10.16 ± 0.25	-23.48 ± 0.16	-5.45 ± 0.10
V383 Lac	BD+48 3686	K1V	0.69	0.83	19.8	2.42	-7.06 ± 1.43	-22.19 ± 0.34	-3.90 ± 0.86
EP Eri	HD 17925	K1V	0.69	0.86	6.2	6.85	-15.01 ± 0.10	-21.80 ± 0.18	-8.68 ± 0.11
DX Leo	HD 82443	K0V	0.64	0.78	6.2	5.377	-9.91 ± 0.15	-22.83 ± 0.36	-5.61 ± 0.23
GJ 211	HD 37394	K1V	0.69	0.84	4.0	10.86	-12.89 ± 0.23	-23.35 ± 0.27	-14.55 ± 0.18
HD 77407	BD+38 1993	G0	0.50	0.61	7.0*		-10.10 ± 0.30	-23.91 ± 0.70	-7.12 ± 0.38
EK Dra	HD 129333	G1.5V	0.52	0.59	17.3	2.787	-7.25 ± 0.32	-29.07 ± 0.42	-4.65 ± 0.35
UMa									
V834 Tau	HD 29697	K4V	0.91	1.09	9.5	3.936	5.71 ± 0.31	-3.60 ± 0.09	-21.04 ± 0.37
π^1 UMa	HD 72905	G1.5V	0.52	0.62	9.7	4.68	11.24 ± 0.09	-0.10 ± 0.10	-10.99 ± 0.09
GJ 503.2	HD 115043	G2V	0.53	0.67	7.5		14.52 ± 0.26	2.19 ± 0.21	-8.08 ± 0.27
Others									
LQ Hya	HD 82558	K2V	0.64	0.91	25	1.66	-20.36 ± 0.35	-5.45 ± 0.17	-9.28 ± 0.28
GJ 577	HD 134319	G5	0.54	0.68		4.448	-32.45 ± 1.05	-13.59 ± 0.35	-2.82 ± 0.20
GJ 3706	HD 105631	K0V	0.64	0.80	4.5		-28.26 ± 0.86	-22.43 ± 0.61	-7.55 ± 1.93
Ref. Stars									
107 Psc	HD 10476	K1V							
GJ 706	HD 166620	K2V							
GJ 758 *	HD 182488	G8V							
HR 8088	HD 201196	K2IV							
GJ 639	HD 151877	K7V							
GJ 679	HD 159222	G5V							
β Oph *	HD 161096	K2III							
61 Cyg A	HD 201092	K5V							
61 Cyg B	HD 201092	K7V							
HR 7949	HD 197989	K0III							
HR 166 *	HD 3651	K0V							
HR 222 *	HD 4628	K2V							
HR 8832	HD 219134	K3/4V							
β Gem *	HD 62509	K0III							
Sun	-	G2V							

by Soderblom et al. (1990). The obtained values are given in Table 3 and plotted in Fig. 2 versus their spectral type.

In order to obtain an estimate of the ages of our stars we compare their EW(Li I) with those of stars in well-known young open clusters of different ages. In the EW(Li I) versus spectral type diagram (Fig. 2) we have overplotted the upper envelope of the Li I EW of IC 2602 (10–35 Myr), the Pleiades (78–125 Myr), and the Hyades (600 Myr), open clusters which cover the range of ages of the MGs studied here. For the Pleiades we adopt the upper envelope determined by Neuhäuser et al. (1997) with data from Soderblom et al. (1993b) and García López et al. (1994) and the lower envelope given by Soderblom et al. (1993b). In the case of IC 2602 we have not adopted the upper envelope given by Neuhäuser et al. (1997) with data from Randich et al. (1997) and Stauffer et al. (1997) because they have used EW(Li I) not corrected for the EW(Fe I) and we have determined a new upper envelope with corrected EW(Li I) and using, in addition, new data provided by Randich et al. (2001). Finally for the Hyades (600 Myr) we have used the upper envelope adopted by Soderblom et al. (1993b).

Representative spectra in the Li I line region of the star sample are plotted in Fig. 3. As can be seen in this figure a prominent Li I absorption line is observed in the stars classified as possible members of the LA except GJ 211. The other LA stars have EW(Li I) between the lower and upper envelope of the Pleiades (see Fig. 2), except EK Dra and HD 77407 which seem to be younger (EW(Li I) between the upper envelopes of the Pleiades and IC 2602). The possible members of the UMa have a lower Li I absorption line corresponding to the greater age of the UMa group (EW(Li I) between the upper envelope of the Hyades and the lower envelope of the Pleiades). The YD stars LQ Hya have a EW(Li I) similar to the upper envelope of the Pleiades. The EW(Li I) of GJ 577 is well above the upper envelope of the Hyades, and no Li I line is detected in GJ 3706.

5. Chromospheric activity indicators

The echelle spectra analysed in this paper allow us to study the behaviour of the different optical chromospheric activity indicators from the Ca II H & K to the Ca II IRT lines, formed at different atmospheric heights. As shown in our previous work (Montes et el. 2000b, and references

Table 3. Radial velocities and Li I EW.

Name	Obs.	MJD	$V_{\rm hel} \pm \sigma_V$ (km s^{-1})	$\overline{V_{\rm hel}} \pm \sigma_V$ (km s^{-1})	EW(LiI+FeI) (mÅ)	EW(LiI) (mÅ)	$\overline{EW}$(LiI) (mÅ)
LA							
PW And	2.2 m 99	51384.1732	−11.76 ± 0.59	−10.99 ± 0.11	290	269	271
	2.2 m 99	51385.0401	−11.49 ± 0.23		283	262	
	2.2 m 99	51386.1011	−12.50 ± 0.37		292	271	
	2.2 m 99	51387.0396	−10.51 ± 0.42		290	269	
	2.2 m 99	51388.1258	−11.95 ± 0.26		277	256	
	2.2 m 99	51389.0818	−11.11 ± 0.47		296	275	
	NOT 99	51508.8690	−9.41 ± 0.25		305	284	
	NOT 99	51509.9022	−10.28 ± 0.28		300	279	
V368 Cep	2.2 m 99	51384.0420	−16.41 ± 0.39	−16.67 ± 0.11	229	213	207
	2.2 m 99	51385.0085	−17.02 ± 0.19		222	206	
	2.2 m 99	51386.1725	−16.58 ± 0.24		231	215	
	2.2 m 99	51387.0935	−16.83 ± 0.32		225	209	
	2.2 m 99	51388.0347	−16.74 ± 0.32		209	193	
	2.2 m 99	51389.0296	−16.50 ± 0.32		226	210	
	NOT 99	51509.8749	−15.72 ± 0.38		220	204	
V383 Lac	2.2 m 99	51384.0141	−19.55 ± 0.49	−20.19 ± 0.12	266	249	257
	2.2 m 99	51384.1565	−19.51 ± 0.49		265	248	
	2.2 m 99	51384.9920	−20.59 ± 0.22		273	256	
	2.2 m 99	51386.0848	−19.98 ± 0.33		277	260	
	2.2 m 99	51387.0233	−20.61 ± 0.40		273	256	
	2.2 m 99	51388.0023	−20.02 ± 0.22		277	260	
	2.2 m 99	51388.9987	−20.19 ± 0.36		284	267	
EP Eri	NOT 99	51508.9395	17.54 ± 0.11	17.54 ± 0.11	231	211	208
	NOT 99	51509.9946			225	206	
DX Leo	NOT 99	51509.2471	8.33 ± 0.11	8.13 ± 0.08	200	184	186
	NOT 99	51510.2689	8.00 ± 0.13		196	180	
	INT 00	51562.1797			188	172	
	INT 00	51564.2121	8.16 ± 0.24		196	180	
	INT 00	51566.1720	7.63 ± 0.24		183	167	
GJ 211	INT 00	51566.0980	0.26 ± 0.17	0.26 ± 0.17	21	2	2
HD 77407	INT 00	51564.1974	4.72 ± 0.23	4.43 ± 0.17	168	160	162
	INT 00	51566.1601	4.08 ± 0.25		173	165	
EK Dra	INT 00	51563.3055	−19.37 ± 0.48	−20.64 ± 0.33	198	189	195
	INT 00	51566.3100	−21.80 ± 0.46		201	202	
UMa							
V834 Tau	NOT 99	51509.0815	0.59 ± 0.17	0.27 ± 0.11	91	65	60
	NOT 99	51510.1062	0.07 ± 0.16		86	60	
	INT 00	51566.0563	−0.13 ± 0.35		80	54	
π^1 UMa	NOT 99	51510.2862	−14.87 ± 0.15	−14.45 ± 0.13	117	107	106
	INT 00	51564.1889	−12.98 ± 0.33		116	106	
	INT 00	51566.1501	−13.82 ± 0.34		115	105	
GJ 503.2	INT 00	51566.2634	−9.26 ± 0.29	−9.26 ± 0.29	101	92	92
Others							
LQ Hya	NOT 99	51509.2635	6.80 ± 0.41	8.26 ± 0.19	259	237	243
	NOT 99	51510.3008	7.97 ± 0.29		277	255	
	INT 00	51564.1761	10.30 ± 0.50		255	233	
	INT 00	51566.1127	8.82 ± 0.37		268	246	
GJ 577	2.2 m 99	51384.8466	−6.45 ± 0.15	−6.48 ± 0.10	160	148	145
	2.2 m 99	51386.8451	−6.52 ± 0.27		165	153	
	2.2 m 99	51388.8314	−6.49 ± 0.14		145	133	
GJ 3706	INT 00	51564.2814	−2.60 ± 0.21	−2.60 ± 0.21	18	1	1

therein) with the simultaneous analysis of the different optical chromospheric activity indicators and using the spectral subtraction technique, it is possible to study in detail the chromosphere, discriminating between the different structures: plages, prominences, flares and microflares.

The chromospheric contribution in these features has been determined using the spectral subtraction technique described in detail by Montes et al. (1995, 1997, 1998, 2000b). The synthesized spectrum was constructed using the program STARMOD developed at Penn State University (Barden 1985) and modified by us. The inactive stars used as reference stars in the spectral subtraction were observed during the same observing run as the active stars. Spectra of representative reference stars in the Ca II H & K, Hβ, Hα, and Ca II IRT line regions are plotted in Fig. 4. In Table 4 we give the excess emission equivalent width (EW) (measured in the subtracted spectra) for the Ca II H & K, Hϵ, Hδ, Hγ, Hβ, Hα, and Ca II IRT (λ8498, λ8542, λ8662) lines, as well as the reference star used in the subtraction technique for each observation. We have

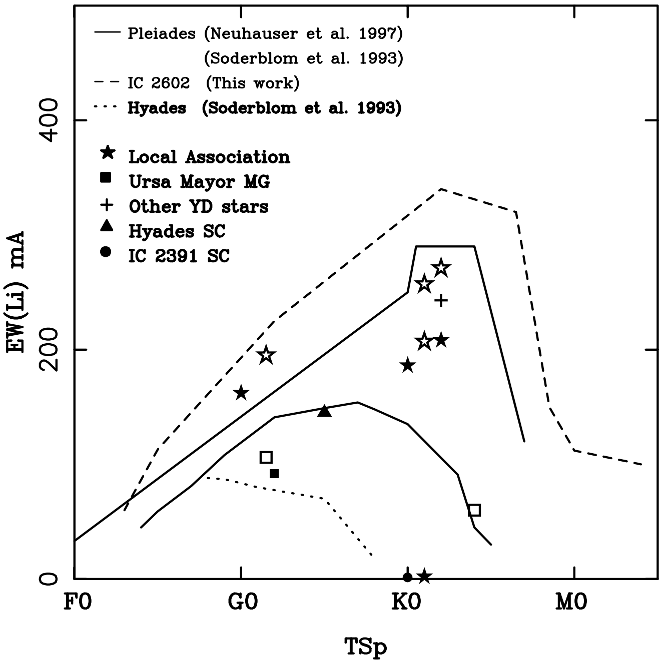

Fig. 2. Li i λ6707.8 line equivalent width, EW(Li i) versus spectral type for our star sample. Symbols are as in Fig. 1. Dashed line represent the upper envelope of EW(Li i) observed in the young open cluster IC 2602; solid lines are the upper and lower envelopes of EW(Li i) in the Pleiades and the dotted line in the Hyades.

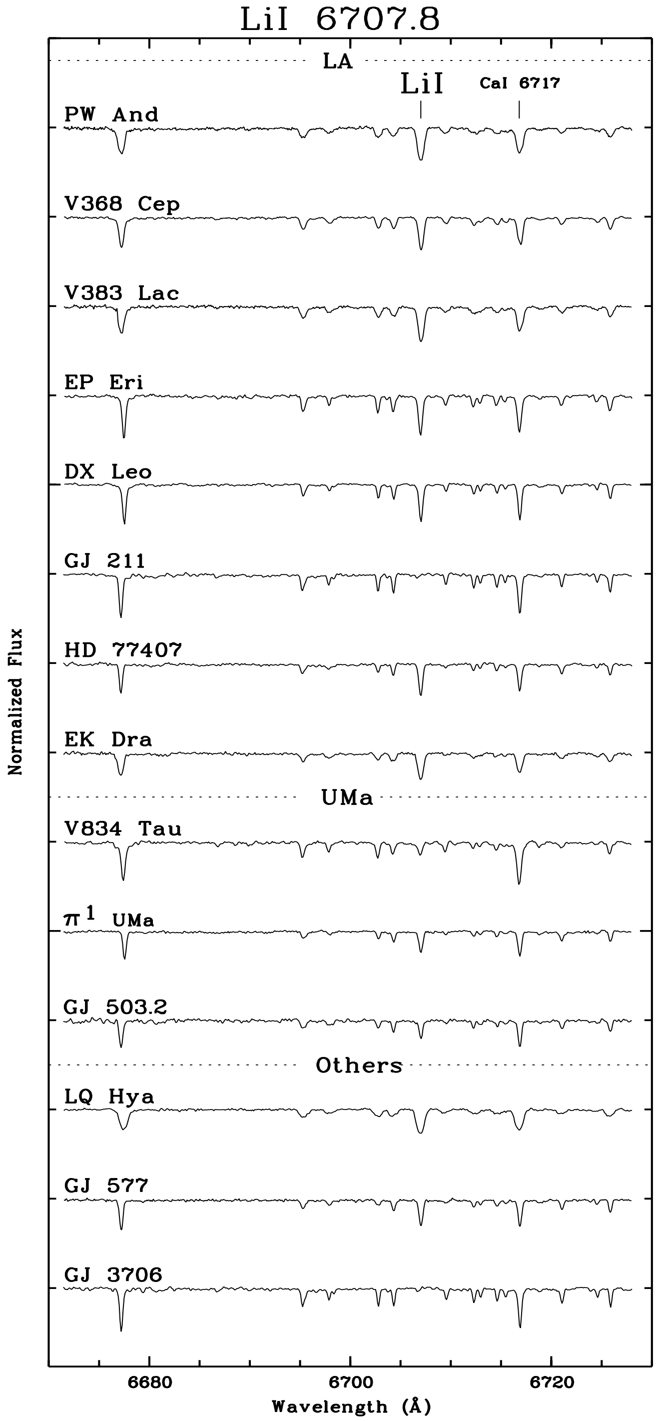

Fig. 3. Spectra in the Li i λ6707.8 line region for our star sample.

estimated the errors in the measured EW taking into account the typical internal precisions of STARMOD (0.5–2 km s^{-1} in velocity shifts, and $\pm$5 km s^{-1} in $v \sin i$), the rms obtained in the fit between observed and synthesized spectra in the regions outside the chromospheric features (typically in the range 0.01–0.03) and the standard deviations resulting in the EW measurements. The estimated errors are in the range of 10–20%. For low active stars errors are larger and we have considered as a clear detection of excess emission or absorption in the chromospheric lines only when these features in the difference spectrum are larger than 3σ. Errors in the chromospheric features of the blue spectral region are larger due to the lower S/N of the spectra in this region. As an indication of the accuracy of the data, we give in Table 1 the S/N in the Ca ii H & K, and Hα line regions. The excess emission EW have been converted to absolute chromospheric flux at the stellar surface by using the calibration of Hall (1996) as a function of $(B-V)$. In Table 5 we give the absolute flux at the stellar surface (log$F_{\rm S}$) for the lines listed in Table 4.

Representative spectra in the Hα and Ca ii IRT (λ8498, λ8542) line regions of the star sample have been plotted in Figs. 5 and 6. For each star we have plotted the observed spectrum (solid-line) and the synthesized spectrum (dashed-line) in the left panel and the subtracted spectrum in the right panel. Hα emission above the continuum is detected in PW And, V834 Tau, and LQ Hya; in the rest of the stars excess Hα emission is detected in the subtracted spectra except GJ 3706. Filled-in absorption in other Balmer lines is also detected in many of the stars. Ca ii H & K emission is observed in all the stars in which these lines are included in our spectra. Emission reversal in the Ca ii IRT lines is observed in PW And, V368 Cep, V383 Lac, DX Leo, EK Dra, V834 Tau, and LQ Hya, in the rest of the stars a filled-in absorption line profile is observed.

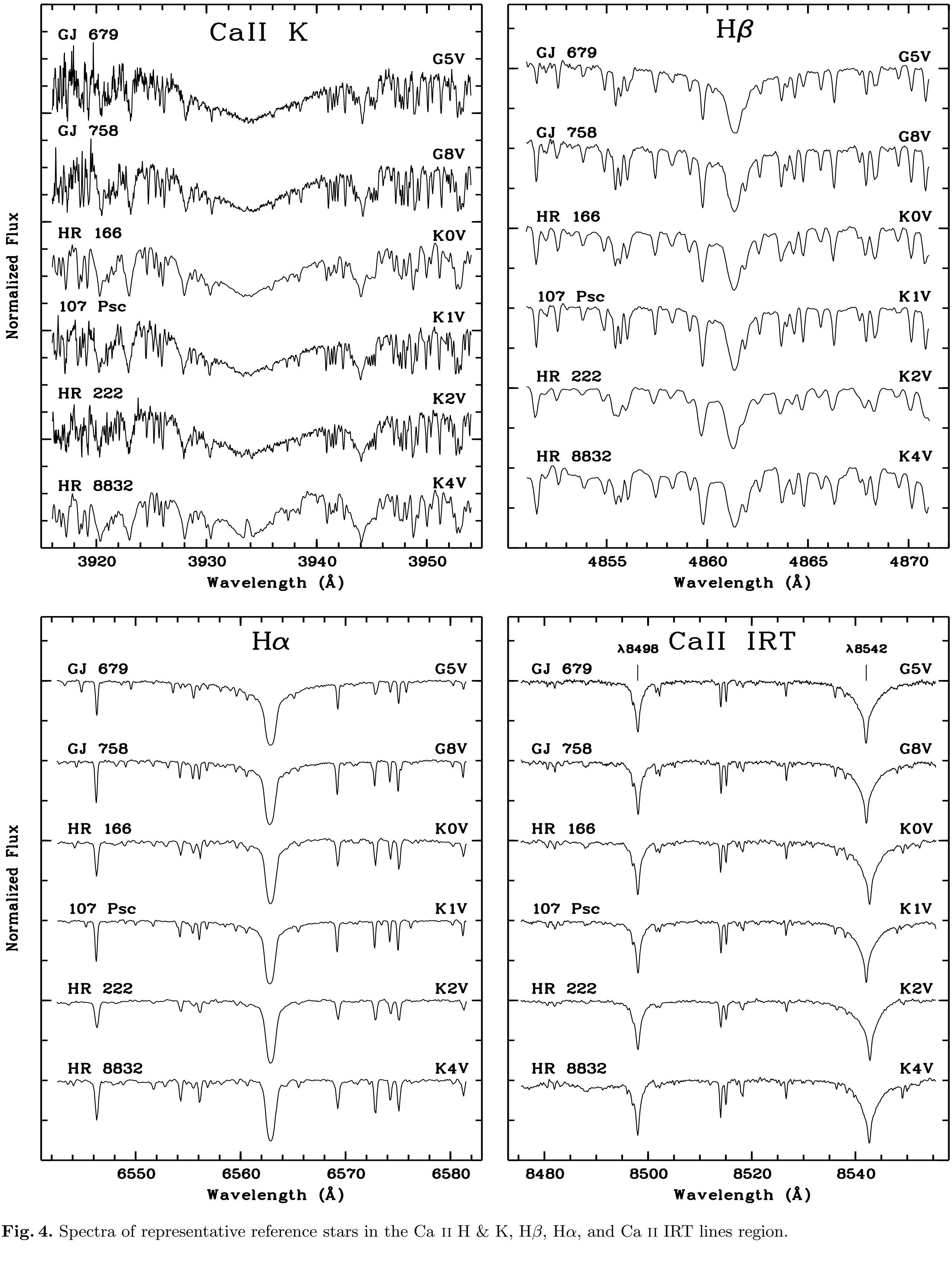

Fig. 4. Spectra of representative reference stars in the Ca II H & K, Hβ, Hα, and Ca II IRT lines region.

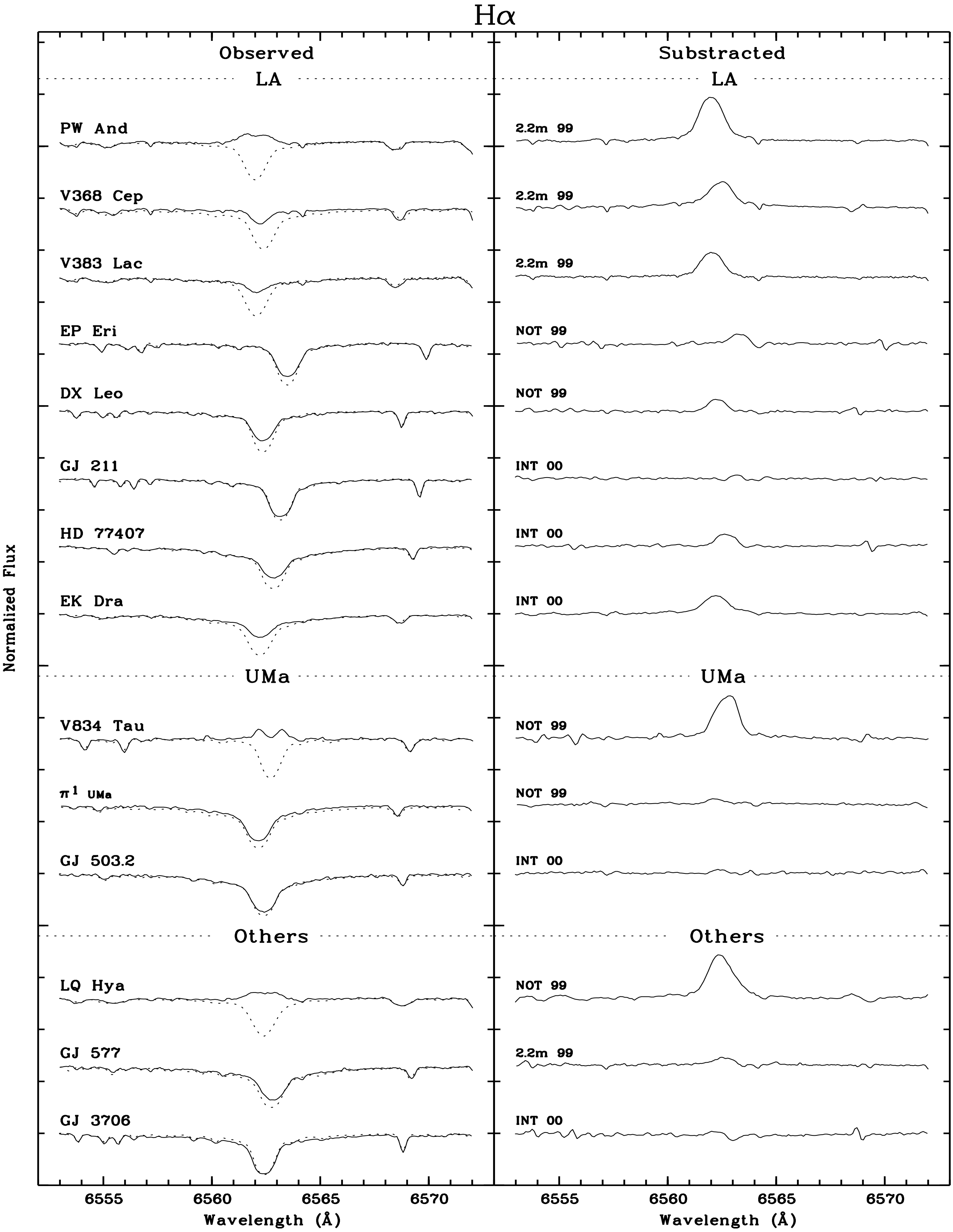

Fig. 5. Spectra in the Hα line region for our star sample. Observed and synthetic spectra are shown in the left panel and subtracted spectra in the right panel.

6. Individual results

In this section we describe the individual results about stellar parameters, kinematic, lithium, chromospheric activity, and membership of the different SKG for each star of the sample.

6.1. PW And (HD 1405)

This solar neighborhood Pleiades-age K2 dwarf (Ambruster et al. 1998) is a fast rotator with a photometric period $P_{\rm phot}$ = 1.745 days (Hooten & Hall 1990) and $v \sin i$ = 23.4 km s^{-1} (Fekel 1997). Strassmeier et al. (1988) listed this star as a chromospherically active binary candidate, however, Griffin (1992) found no evidence of variability in their radial velocities, indicating it is a single star. The mean radial velocity determined by us ($v_{\rm r} = -10.99$ km s^{-1}) is very similar to the values given by Fehrenbach & Burnage (1982) ($v_{\rm r} = -11.5$ km s^{-1}) and Griffin (1992) ($v_{\rm r} = -10.4$ km s^{-1}) supporting the single nature of this star. We have found, however, small amplitude radial velocity variations which follow the rotational period (1.75 days) of the star. These variations can be associated with photospheric spots that disturb the line profile of this rapidly rotating star. Bidelman (1985) and Christian et al. (2001) reported moderate Ca II H & K emission and the Hα line in emission in this star. Chromospheric and transition region UV emission fluxes have been reported by Ambruster et al. (1998) and Wood et al. (2000). In addition, it has been detected by the ROSAT-satellite as the 2RE J001820+305 source (Pye et al. 1995; Kreysing et al. 1995; Thomas et al. 1998; Rutledge et al. 2000), and by the EUVE-satellite as the EUVE J0018+309 source (Malina et al. 1994; Christian et al. 2001). In the eight spectra of this star that we have analysed, we have found intense emission in the Ca II H & K and Hϵ lines, strong Hα emission above the continuum (see Fig. 5), excess chromospheric emissions in the other Balmer lines, and emission reversal in the Ca II IRT lines (Fig. 6). We have detected variations in the excess emission of the different chromospheric lines, specially in the Balmer lines. High Li I abundance indicative of a Pleiades-age star is reported by Ambruster et al. (1998). The EW(Li I) = 271 mÅ we have determined confirms it is a young star. The space motions and all the other spectroscopic properties we have analysed prove its LA membership.

6.2. V368 Cep (HD 220140, HIP 115147)

This star is the optical counterpart of the X-ray source H 2311+77 (Pravdo et al. 1985) and has been identified as member of the LA and classified as a post T Tauri star (Chugainov et al. 1991a, 1993; Ambruster et al. 1998; Kahanpää et al. 1999). The spectral type of this star in the literature ranges from G5 to K2V, but the recent photometric observations of Kahanpää et al. (1999) support a K1V spectral type. It is a rapidly rotating and spotted star with a photometric period $P_{\rm phot}$ = 2.74 d (Kahanpää et al. 1999). and $v \sin i$ = 16.1 km s^{-1} (Fekel 1997). From our six spectra taken in July 1999 and another one taken in November 1999 we have determined a constant radial velocity with a mean value of -16.67 km s^{-1}, which is within the range given in the literature (15–17 km s^{-1}, Chugainov et al. 1991a), supporting its classification as a constant-velocity star. Evidence of magnetic activity including strong Ca II H & K emission, IUE-, EUVE- and ROSAT-satellite detections have been reported for this star (Bianchi et al. 1991; Malina et al. 1994; Pye et al. 1995). In our spectra we observe intense emission in the Ca II H & K and Hϵ lines, strong and variable excess chromospheric emissions in the Balmer lines, specially in Hα (Fig. 5), and the Ca II IRT lines in emission superimposed on the corresponding absorption (Fig. 6). Chugainov et al. (1991a) report a Li I λ6707.8 Å line stronger than the Ca I λ 6717 Å line with a EW(Li I) = 288 mÅ. In our spectra the Li I absorption feature is also stronger than the Ca I line but the mean EW we have obtained after the correction of the Fe I line is EW(Li I) = 207 mÅ which is similar to EW(Li I) observed in Pleiades stars of this spectral type (Fig. 2). However, this EW(Li I) is not high enough to consider the star as a post T Tauri star (see the EW(Li I) vs. spectral type diagram by Martín 1997). Both kinematic and spectroscopic criteria indicate V368 Cep is a bona fide member of the LA.

6.3. V383 Lac (BD+48 3686)

Recent spectroscopic and photometric studies of V383 Lac (Mulliss & Bopp 1994; Jeffries 1995; Henry et al. 1995; Fekel 1997; Osten & Saar 1998) concluded it is a single active K1V star with an age less than of the Pleiades and with a rapid rotation. These authors report a photometric period $P_{\rm phot}$ = 2.42 days and $v \sin i$ ranging from 14 to 20 km s^{-1}. The mean radial velocity determined from our seven spectra ($v_{\rm r} = -20.19$ km s^{-1}) shows no evidence of variability and it is in agreement with the range of values (from -19.4 to -22.1 km s^{-1}) given in the literature, supporting the conclusion that it is a single star. Mulliss & Bopp (1994) found the Hα and Ca II IRT lines filled by emission. It has been detected as an extreme ultraviolet source (Pye et al. 1995; Lampton et al. 1997). In our spectra, which cover more than one stellar rotation, we have found notable emission in the Ca II H & K and Hϵ lines, excess chromospheric emission in the Balmer lines and emission reversal in the Ca II IRT lines. During one of the nights a noticeable increase in the excess emission is detected, showing the Hα line large emission wings. This variation could be due to a small-scale flare or to the transit of an active region. We have determined a EW(Li I) = 257 mÅ, similar to the values of 250 and 277 mÅ given by Mulliss & Bopp (1994) and Jeffries (1995) respectively. This high EW(Li I) (close to the upper envelope of the Pleiades) indicates it is a young star. The space motions and all the other spectroscopic characteristic we have analysed in this star confirm it is a member of the LA.

6.4. EP Eri (HD 17925, GJ 117, HIP 13402)

This is a very nearby (8 pc), very young (high Li I abundance) active K2-type dwarf with a rotation period of 6.85 days (Cutispoto 1992; Henry et al. 1995). The presence of an unresolved companion in this star has been suggested by Henry et al. (1995) based on the variable widths of the photospheric absorption lines reported in the literature ($v \sin i$ range from 3 to 8; see Fekel 1997). Wood et al. (2000) also suggest that an unresolved secondary can be contributing to the emission Mg II h and k lines. However, no evidence or velocity variability is reported in the literature (Halbwachs et al. 2000) and the radial velocity we have determined (17.5 km s^{-1}) is in good agreement with that of Beavers & Eitter (1986) 18.8 km s^{-1}, and Henry et al. (1995) 18.1 km s^{-1}. Cutispoto et al. (2001) also indicate that the binary hypothesis does not seem to be consistent with the Hipparcos photometric data. Strong Ca II H & K emission and a filled-in Hα line have been found by Pasquini et al. (1988) and Henry et al. (1995). Chromospheric and transition region UV emission fluxes have been reported by Ambruster et al. (1998) and Wood et al. (2000). It is also an X-ray and EUV source (Favata et al. 1995; Jeffries 1995; Lampton et al. 1997). In our spectra we have found Ca II K emission and excess chromospheric emission in the Hα and the Ca II IRT lines. EP Eri is a young star as indicated by the strong lithium line detected by Cayrel de Strobel & Cayrel (1989). We have measured a EW(Li I) = 208 mÅ, similar to the 197 mÅ given by Favata et al. (1995) and the 205 mÅ obtained by Jeffries (1995). Recently, additional evidence of youth has been reported. An age of 80 Myr has been estimated by Lachaume et al. (1999) and a IR excess (ISO 60 μm) has been detected in this star and attributed by Habing et al. (2001) to a circumstellar disk (Vega-like). Ambruster et al. (1998) identified it as member of the LA, and the kinematic data analysed by Cayrel de Strobel & Cayrel (1989) show that the birth-place of this star is associated with the Scorpio-Centaurus complex. The position in the (U, V) ad (U, W) planes we have determined as well as the spectroscopic criteria are in agreement with its LA membership.

6.5. DX Leo (HD 82443, GJ 354.1, HIP 46843)

This is a nearby, young and active K0 dwarf with space motion very similar to the LA (Soderblom & Clements 1987; Ambruster et al. 1998; Gaidos et al. 2000). Optical flux modulation with a period of 5.4 days attributed to cool photospheric spots have been found by Henry et al. (1995), Messina et al. (1999b), and Gaidos et al. (2000). A projected rotational velocity $v \sin i$ = 6.2 is given by Fekel (1997). DX Leo is a single star as indicates the constant radial velocity we have determined in our spectra, $v_{\rm r}$ = 8.13 km s^{-1}, and the values of $v_{\rm r}$ = 8.2, 8.9, and 8.25 km s^{-1} given by Duquennoy et al. (1991), Griffin (1994), and Henry et al. (1995) respectively. Strong chromospheric and transition region line emissions have been reported by Soderblom & Clements (1987), Basri et al. (1989), Ambruster et al. 1998; Strassmeier et al. (2000), and Wood et al. (2000). It is also a X-ray and EUV source (Pye et al. 1995; Hünsch et al. 1999). In our spectra, taken in two different epochs, we have found noticeable emission in the Ca II H & K and Ca II IRT lines, and excess chromospheric emission in the Hα line. We have obtained a EW(Li I) = 198 mÅ which is within the range observed in the Pleiades and similar to the value of EW(Li I) = 187 mÅ given by Strassmeier et al. (2000). The space motion we have determined and all the spectroscopic criteria we have analysed indicate DX Leo is a young star member of the LA.

6.6. GJ 211 (HD 37394, HR 1925)

This is a nearby star classified as a possible member of the LA (Jeffries & Jewell 1993; Gaidos et al. 2000). It is a K1V slowly rotating star ($P_{\rm phot}$ = 10.86 d, and $v \sin i$ = 4.0 km s^{-1}, Gaidos et al. 2000) but with evidence of chromospheric activity (emission in the Ca II H & K and Mg II h & k lines, Soderblom & Clements 1987) and coronal activity (EUV and X-ray emission Hünsch et al. 1999). It has even been classified by some authors (Gershberg et al. 1999) as a flare star. Unlike EP Eri, Habing et al. (2001) have not detected evidence of circumstellar disk in the IR (ISO 60 μm) flux of this star. Constant radial velocity has been reported for this star with values ranging from −0.2 to 2 km s^{-1}, which are in agreement with the $v_{\rm r}$ = 0.26 km s^{-1} we have determined. In our spectrum we observe small excess chromospheric emission in the Balmer lines and Ca II IRT lines and a very small EW(Li I) (2.0 mÅ) in agreement with the EW(Li I) = 1.3 ± 3.2 mÅ reported by Gaidos et al. (2000). The space motions calculated by us are consistent with the LA but the low level of chromospheric emission and very small EW(Li I) indicate it is not a young star and probably it is not a member of the LA.

6.7. HD 77407 (BD+38 1993, HIP 44458)

This G0 star was included in the study of the Hyades and Sirius MGs by Eggen (1986), but not identified as a member of any of these MGs. It is an X-ray/EUV source detected by ROSAT and EUVE (Lampton et al. 1997) and also detected as a stellar radio source by Helfand et al. (1999). However, it is a very little-studied star, and no previous determinations of radial velocity, rotation, chromospheric activity and lithium have been reported in the literature. Using our two spectra of this star we have determined a mean radial velocity of 4.43 km s^{-1}, which together with the astrometric data results in a Galactic space motion (U, V, W) similar to the LA.

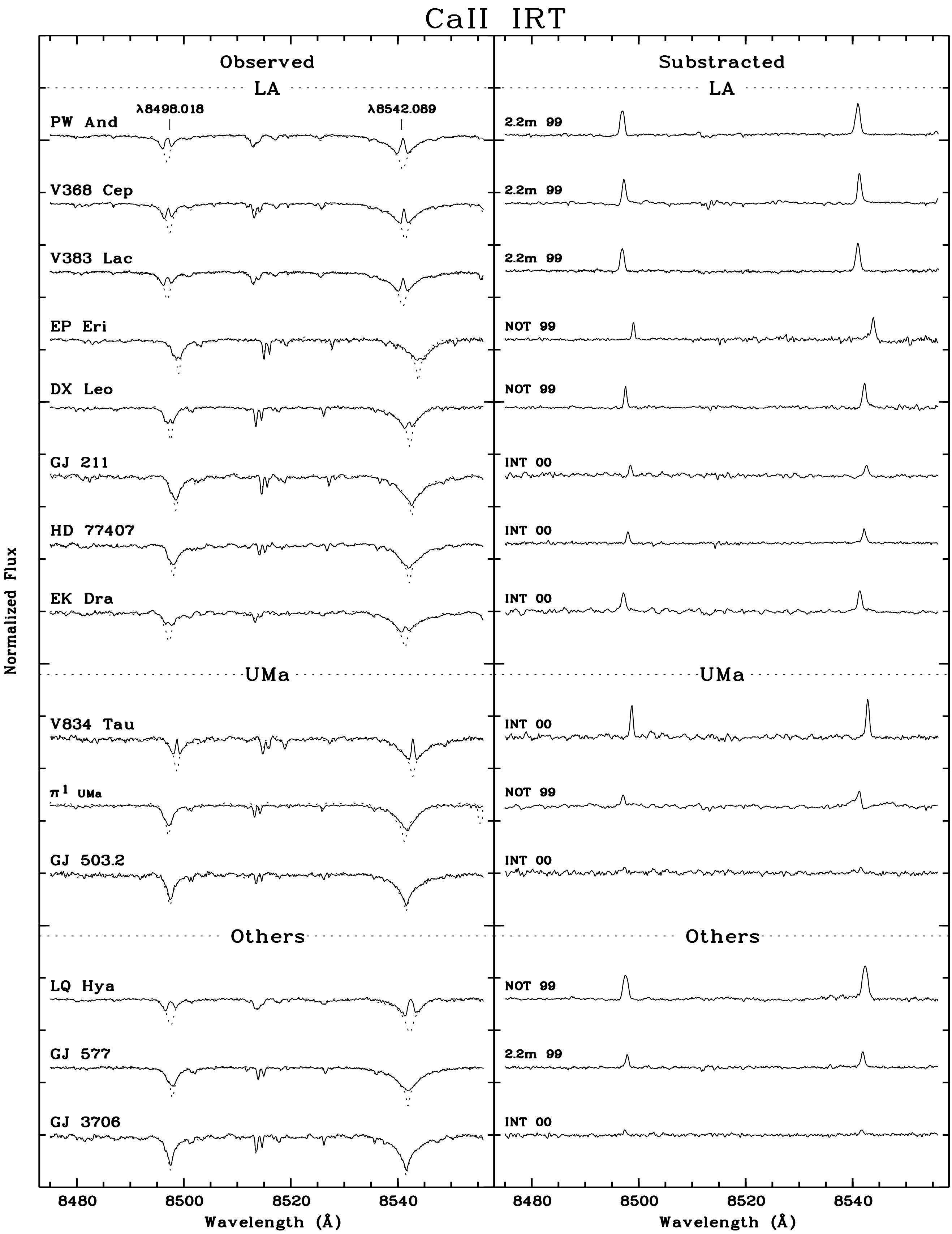

Fig. 6. Spectra in the Ca II IRT (8498, 8542 Å) line region for our star sample. Observed and synthetic spectra in the left panel and subtracted spectra in the right panel.

Eggen's kinematic criteria also confirm their membership of the LA. Our spectra show that it is a slow rotating star ($v \sin i \approx 7$ km s^{-1}) with a notable chromospheric excess emission in the $H\beta$, $H\alpha$, and Ca II IRT lines. The EW(Li I) = 162 mÅ we have determined lies above the upper EW(Li I) envelope of the Pleiades (as also reported by Wichmann & Schmitt 2001), indicating that it is a very young star and therefore a probable member of the LA.

6.8. EK Dra (HD 129333, GJ 559.1A, HIP 71631)

This nearby G1.5V spotted and very active star (Strassmeier & Rice 1998; Strassmeier et al. 2000) was previously identified as a member of the LA (Chugainov 1991; Chugainov et al. 1991b; Soderblom & Clements 1987) and considered as a young solar analog (Dorren & Guinan 1994). It is a rapidly-rotating star with $v \sin i$ 17.3 km s^{-1} and with a photometric period ranging in the literature from 2.6 to 2.8 days (Chugainov et al. 1991b; Dorren & Guinan 1994; Strassmeier & Rice 1998; Messina et al. 2001; DePasquale et al. 2001). EK Dra can be treated essentially as a single star, although Duquennoy & Mayor (1991) have suggested that it may be a member of a long-period ($\approx$12.5 yr) binary system with radial velocity variations between -21 and -32 km s^{-1} and $v_0 = -23.1$ km s^{-1}. Dorren & Guinan (1994) found a mean radial velocity of -24 km s^{-1}, Fehrenbach et al. (1997) give -18 km s^{-1} and we have obtained in our spectra a mean value of -20.6 km s^{-1}. High levels of magnetic activity have been detected in this star: strong Ca II H & K emission (Soderblom 1985); variable UV chromospheric emission lines (Dorren & Guinan 1994; Saar & Bookbinder 1998); and X-ray and EUV emission (Güdel et al. 1997; Audard et al. 2000). In our spectra we observe a small emission reversal in the Ca II IRT lines and a notable excess emission in the $H\alpha$ and $H\beta$ lines. Strong Li I absorption has been reported previously in the literature for this star (see Wichmann & Schmitt 2001). In our spectra we have determined a EW(Li I) of 198 mÅ, which is between the upper envelopes of the Pleiades and IC 2602, indicating that this star is significantly younger than the Pleiades open cluster. The space motion, high level of magnetic activity, and strong Li I absorption observed in this star confirm that it is a member of the LA.

6.9. V834 Tau (HD 29697, GJ 174, HIP 21818)

This very active K4V star was considered for some time (Strassmeier et al. 1993) as candidate to chromospherically active binary. However, the constant radial velocities measured by several authors (Fouts & Sandage 1986; Henry et al. 1995; Halbwachs et al. 2000) and our radial velocity determination ($v_{\rm r}$ = 0.27 km s^{-1}) indicate that it is a single star. Light variations were first discovered in this star by Chugainov (1981), later, Henry et al. (1995) determined a photometric period of 3.936 days and Fekel (1997) measured a rotational velocity, $v \sin i = 9.5$ km s^{-1}. Exceptional strong Ca II H & K emission lines (Young et al. 1989), modest Hα emission above the continuum (Rutten et al. 1989; Henry et al. 1995) and Radio, X-ray and EUV emission (Güdel 1992; Pye et al. 1995; Hünsch et al. 1999) have been detected in this star. In our spectra taken at two different epochs we have found strong emission in the Ca II K line, the Hα line in emission above the continuum with a central self-absorption, a filled-in absorption Hβ line, and the Ca II IRT lines in emission. Chugainov (1991) and Eggen (1996) listed V834 Tau as a young disk star and Chugainov (1991) suggested it as a possible member of the LA. However, the Galactic velocity components we have determined indicate it is a possible member of the UMa. The lithium line has been detected in this star; Henry et al. (1995) give a EW(Li I) = 79 mÅ, and we have determined in our spectra a EW(Li I) = 60 mÅ. This notable EW(Li I) (see Fig. 2) indicates it is a young star and confirms its membership of the UMa.

6.10. π^1 UMa (HD 72905, GJ 311, HIP 42438)

This nearby G1.5V active star, considered as proxy of the young Sun (Bochanski et al. 2001), has been classified as a possible member of the UMa moving group by Soderblom & Clements (1987); Soderblom & Mayor (1993a); Gaidos (1998); and Gaidos et al. (2000). It has a $v \sin i$ = 9.5 km s^{-1} (Fekel 1997) and a short rotation period ($P \approx 4.8$ days) as measured by periodic light variations due to starspots by Gaidos et al. (2000) and Bochanski et al. (2001). The mean radial velocity we have determined ($v_{\rm r} = -14.45$ km s^{-1}) is similar to the value reported by Duquennoy et al. (1991) ($v_{\rm r} = -12.66$ km s^{-1}). π^1 UMa has high levels of chromospheric and coronal activity (Soderblom & Mayor 1993a,b; Dorren & Guinan 1994). A superflare (Schaefer et al. 2000) was detected in this star in the X-ray band by the EXOSAT satellite (Landini et al. 1986). In our observations we have found small excess chromospheric emissions in the Hα, and the Ca II IRT lines. We have determined a EW(Li I) = 106 mÅ, very close to the value of 96 mÅ given by Soderblom et al. (1993a). This EW(Li I) is intermediate between the Hyades upper envelope and Pleiades lower envelope, corresponding to the age of the UMa. Our new calculation of the galactic velocity components and the spectroscopic criteria above-described are in agreement with the membership of this star to the UMa.

6.11. GJ 503.2 (HD 115043, BD+57 1425, HIP 64532)

This nearby G2V star is classified as a member of the UMa group by Eggen (1992) and Soderblom & Mayor (1993a). It is a slow rotating star with $v \sin i = 7.5$ km s^{-1} (Soderblom & Mayor 1993b). Duquennoy et al. (1991) reported a constant radial velocity ($v_{\rm r} = -8.86$ km s^{-1}) for this star, which is very similar to the value determined in our spectrum ($v_{\rm r} = -9.26$ km s^{-1}) confirming it is a single star. Evidence of magnetic activity has been found in the X-ray by the ROSAT (Hünsch et al. 1999) and in the ultraviolet by the IUE (Soderblom & Clement 1987) and the HST (Lamzin 2000). Moderate Ca II H & K chromospheric emission is reported by Soderblom (1985). In our spectra we have found a very small fill-in in the Hα and Ca II IRT lines. The Galactic velocity components we have determined and the kinematic criteria are compatible with the star being a member of the UMa. In addition, the EW(Li I) of 92 mÅ determined in our spectrum, which is similar to the value of 77 mÅ given by Soderblom et al. (1993a), indicates an age intermediate between the Hyades and Pleiades corresponding to the UMa. All this supports that GJ 503.2 is a bona fide member of the UMa.

6.12. LQ Hya (HD 82558, GJ 355, HIP 46816)

This star is a young single K2 dwarf classified as a BY Dra variable (Fekel et al. 1986). It is a rapidly rotating star with $v \sin i = 26.5$ km s^{-1} (Donati 1999) and with a photometric rotational period of 1.600881 days (Strassmeier et al. 1997). It is a very active star, as indicated by emission in several chromospheric and transition region lines, even with occasional flares (see Montes et al. 1999 and references therein). EUV and X-ray emission and X-ray flares have been detected in this star (see Covino et al. 2001 and references therein). In our four spectra taken at two different epochs we observed strong emission in the Ca II K line, the Hα line in emission above the continuum with an intensity similar to that observed in the quiescent spectra by Montes et al. (1999), a filled-in absorption Hβ line, and the Ca II IRT lines in emission. We have determined a mean radial velocity, $v_{\rm r}$ = 8.26 km s^{-1}, very close to the mean value of 7.3 km s^{-1} reported by Fekel et al. (1986), 7.5 km s^{-1} given by Vilhu et al. (1991), and 9.0 km s^{-1} by Donati et al. (1997), confirming it is a constant radial velocity star. Eggen (1984b) suggested that LQ Hya may be a member of the HS, Fekel et al. (1986), using their new radial velocity, found it should be considered only as a YD star, however, Chugainov (1991) and Ambruster et al. (1998) listed this star as a member of the LA. The U, V and W velocity components we have calculated using the astrometric data from Tycho-2 Catalogue and the radial velocity determined by us indicate that this star is a YD star but not a member of the LA. It is, however, a young star as pointed out by the strong lithium absorption line (EW(Li) I = 234 mÅ) reported by Fekel et al. (1986). In our spectra we have obtained a similar mean EW(Li) I of 243 mÅ, which is close to the upper envelope of the Pleiades cluster.

6.13. GJ 577 (IU Dra, HD 134319, HIP 73869)

Messina & Guinan (1998) and Messina et al. (1999a) considered this G5V star as a proxy for the young Sun and classified it as a probable member of the HS according with its U, V, W components and parallax. These authors found high levels of photospheric magnetic activity in this star and reported a photometric rotation period of 4.448 days. The mean radial velocity we have determined with our three spectra ($v_{\rm r}$ = −6.48 km s^{-1}) is very close to the constant radial velocity ($v_{\rm r}$ = −6.38 km s^{-1}) given by Duquennoy et al. (1991), confirming it is likely a single star. Soderblom (1985) found moderate chromospheric emission in this star. Moderate Ca II H & K emission is observed in our spectra, however, the Hϵ line is not in emission. In addition, a notable filling-in is detected in the Hα and Ca II IRT lines. The behaviour of the lithium (λ6707.8 line) in this star has not been previously reported in the literature. We have determined in our spectra a EW(Li I) of 145 mÅ which is well above the upper envelope of the Hyades and close to the lower envelope of the Pleiades (see Fig. 2). Even though this star could be considered as member of the HS based on its position in the (U, V) plane and the kinematic criteria, the EW(Li I) indicates it is too young to be a member of the HS.

6.14. GJ 3706 (HD 105631, BD+41 2276, HIP 59280)

This K0V star was classified as a member of the IC 2391 supercluster by Eggen (1991). The radial velocity we have determined for this star ($v_{\rm r}$ = −2.6 km s^{-1}) is in agreement with the previous value ($v_{\rm r}$ = −3.1 km s^{-1}) reported by Duflot et al. (1995). This star is listed by Hünsch et al. (1999) as source of X-ray detected by the ROSAT-satellite and Strassmeier et al. (2000) found slight Ca II H&K emission. In our spectrum we have found a very low level of chromospheric activity (no filled-in is detected in Hα and a very slight filled-in is observed in the Ca II IRT lines). The Li I absorption line is practically not detected in our spectrum (EW(Li I) = 1.4 mÅ) indicating it is not a young star and probably not a member of the IC 2391 SC, in spite of the fact that the kinematic criteria point out that it is a member of this SC.

7. Discussion and conclusions

In this paper we have used high resolution echelle spectroscopic observations to test the membership of 14 single late-type stars to young stellar kinematic groups such as the Local Association (20–150 Myr), Ursa Major group (300 Myr), Hyades supercluster (600 Myr), and IC 2391 supercluster (35 Myr). We have determined accurate heliocentric radial velocities, equivalent width of the Li I doublet at λ6707.8 Å, and the level of chromospheric activity using different indicators from the Ca II H & K to the Ca II IRT lines. All these data allow us to apply both kinematic (position in the (U, V) and (W, V) planes and Eggen's criteria, see Paper I) and spectroscopic (chromospheric activity, and EW(Li I)) criteria.

Using the kinematic criteria we have classified PW And, V368 Cep, V383 Lac, EP Eri, DX Leo, GJ 211, HD 77407, and EK Dra as possible members of the LA. The EW(Li I) and level of chromospheric activity of all these stars, except GJ 211, indicate ages similar to the

Pleiades or even younger than the Pleiades (HD 77407 and EK Dra) confirming their membership to the LA. However, the low level of activity and the Li I line close to the limit of detection we have found in GJ 211 indicate an age older than the range of ages assigned to this SKG and that this star should be rejected as a possible member.

V834 Tau, π^1 UMa, and GJ 503.2 turn out to be possible members of the UMa according to the kinematic criteria. The spectroscopic criteria also confirm their membership. We have found for these three stars a moderate level of chromospheric activity, and a EW(Li I) between the upper envelope of the Hyades and the lower envelope of the Pleiades, that corresponds to the age of 300 Myr of the UMa group, which is intermediate between the Pleiades and Hyades.

The previously identified member of the LA, LQ Hya, turns out to be a YD star (i.e. space-velocity components inside the boundaries that determine the young disk population) but with no clear membership of any of the young SKG studied here. However, the spectroscopic criteria confirm it is a young star with EW(Li I) similar to the upper envelope of the Pleiades and the Hα line in emission above the continuum.

GJ 577 was previously classified as a member of the HS, and the kinematic criteria we have applied confirm this classification. However, the EW(Li I) well above the upper envelope of the Hyades that we have determined for this star indicates that it is younger than the age assigned to the HS.

Even though GJ 3706 could be considered as a member of IC 2391 according to the kinematic criteria, the very small EW(Li I) we have determined in our spectrum indicates an age too old to be a member of the very young IC 2391 SKG.

An additional age estimation of these stars and those for the possible late-type stars members of young SKG we have selected in Paper I can be obtained by isochrone fitting on the color-magnitude diagram. We are carrying out this kind of study in our ongoing project dedicated to the detailed study of each young SKG and the results will be addressed in forthcoming papers.

Some stars have been observed at different nights and at different epochs, covering several rotational periods. The radial velocities we have determined in these spectra show no evidence of variability and are in good agreement with the range of values previously reported by other authors, supporting the single nature of these stars. For some of these stars (with several spectra available) we have also found low level variability of the chromospheric emission, which can be attributed to low level flaring (V383 Lac) or the rotational modulation of chromospheric active regions (PW And, V368 Cep).

The stars with the highest levels of chromospheric activity (LQ Hya, V834 Tau, PW And) have the Hα line in emission above the continuum and also have the highest excess emissions in the Ca II H & K and Ca II IRT lines. These three stars are also the most rapidly-rotating stars of the sample with rotation period, $P_{\rm phot} < 2$ days.

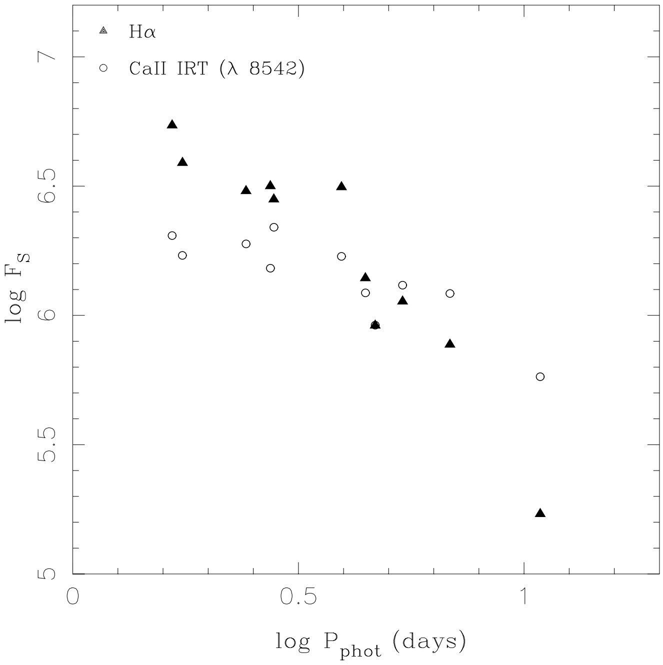

Fig. 7. Absolute flux at the stellar surface in the Hα, and Ca II IRT lines versus photometric period.

When we analyse in detail the behaviour of the chromospheric excess emissions with the star rotation (characterized by their photometric period, $P_{\rm phot}$ or their projected rotational velocity, $v \sin i$, given in Table 2) a clear trend of increasing activity with increasing rotation is revealed. This can be seen in Fig. 7, where we have plotted the absolute flux at the stellar surface (log$F_{\rm S}$) in the Hα, and Ca II IRT lines versus the photometric period (log$P_{\rm phot}$).

This behaviour confirms that this group of young stars also follows a rotation-activity relation similar to that observed in other kinds of active stars (see Montes et al. 1995), and in stars members of young open clusters (see Simon 2001, and references therein). Chromospheric and transition region (using UV emission lines) rotation-activity relations have been previously reported by Ambruster et al. (1998) for five of the stars of our sample.

A more detailed analysis of the relative behaviour of the different diagnostics between themselves and with respect to the main stellar parameters of some of these stars including additional spectroscopic observations will be addressed in forthcoming papers.

We have already started a program of high resolution echelle spectroscopic observations of a large sample of late-type stars (selected by us in Paper I as possible members of young SKGs) in order to carry out a spectroscopic analysis similar to that described in this paper, and in this way better establish their membership of different SKGs (for preliminary results of this spectroscopic survey see Montes et al. 2001c).

Acknowledgements. We would like to thank Dr. B. H. Foing for allowing us to use the ESA-MUSICOS spectrograph at Isaac Newton Telescope. This research has made use the of the

SIMBAD data base, operated at CDS, Strasbourg, France, and the ARI Database for Nearby Stars, Astronomisches Rechen-Institut, Heidelberg. We would also like to thank the referee S. Catalano for suggesting several improvements and clarifications. This work was supported by the Universidad Complutense de Madrid and the Spanish Dirección General de Enseñanza Superior e Investigación Científica (DGESIC) under grant PB97-0259.

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